UNIVERSITI PUTRA MALAYSIA

THE DESIGN OF CRUDE PALM OIL CLARIFIER

SULAIMAN A. S. AL-ZUHAIR

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By

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LIST OF ABBREVIATIONS

a_a	Pre-exponential factor for the Arhenious equation
a_e	External acceleration
a_v	Specific surface
A	Area
A_p	Maximum projection area
A_u	Underflow output area
BOD	Biological Oxygen Demand
C	Concentration
C_D	Drag coefficient
C_f	Oil content in fresh feed
C_r	Oil content in recycle
C_l	Concentration of the limiting layer
C_o	Initial concentration
COD	Chemical Oxygen Demand
C_u	Underflow concentration
CPO	Crude Palm Oil
d_d	Diameter of drop
d_{di}	Mean drop diameter
d_{do}	Initial drop diameter
d_d*	Drop diameter at the coalescence interface
d_p	Diameter of particle
dv/dt	Acceleration of the body
D	Depth of the sedimentation tank

DOC	Dissolved organic compounds
E_{av}	Activation energy
f_e	Porosity ratio
F	Fresh feed
F_b	Buoyancy force
F_d	Drag force
F_e	External force
F_p	Flux of the settling particle
F_u	Flux to provide bulk flow of the underflow
h_c	Sludge interface height
h_p	Dense-packed height of batch system
h_s	Sedimentation height of batch system
h_{coo}	Ultimate sludge interface height
H	Height of dispersion
H_c	Height of the compression zone at critical concentration
H_p	Dense-packed height
H_s	Sedimentation height
H_{oo}	Height of the compression zone at infinite time
k	Constant
L_o	Input volumetric flow rate
L_u	Underflow volumetric flowrate
m	Mass of particle
M_l	Mass of liquid in the compression zone
M_s	Mass of solids in the compression zone

n	Power law exponential constant
n'	The average number of n for the measured temperature range
N	Number of drops
NOS	Non Organic Solids
Q_o	Recovered oil
POME	Palm Oil Mill Effluent
PORIM	Palm Oil Research Institute of Malaysia
Q_c	Continuous throughput
Q_d	Dispersion phase throughput
r	Radius of centrifugal path
R	Gas constant
$Re*$	Power law Reynold's number
S_{ij}	Sedimentation coefficient
ST	Surface Tension
t	Time needed to drops to reach the coalescence interface
t_c	Critical time
t_L	Time of the limiting layer reaching the interface
t_o	Incubation time needed for the drop to grow from zero to d_{do}
t_p	Thickness of plates
t_u	Underflow time
T	Temperature
v	Velocity
v_i	Settling velocity of solid particles
v_h	Velocity of discrete particle in a cloud of similar particles

v_t'	Rising velocity of the layer
V	Volume
V_o	Surface loading rate without plates
V_o'	Surface loading rate with plates
w	Width distance
X_f	Mass fraction of the feed
Y_i	volume rate of coalescence per unit area
Z_c	Critical height
Z_l	Height of the interface at t_L
Z_o	Initial height
Z_u	Underflow height

Greek letters

α	Angle of inclination
ε_I	Hold-up at the coalescence interface
ε'	Mean hold-up
ε^*	Hold-up at coalescence interface
ϕ_j	Volume fraction of particle j
γ	Shear rate
γ_i	Shape factor
η_a	Apparent viscosity
λ	Diameter ratio
μ	Viscosity
ρ_f	Density of fluid

ρ_j	Density of particle species j
ρ_l	Density of liquid
ρ_p	Density of particles
ρ_s	Density of solids
τ	Shear stress
τ_b	Instantaneous binary coalescence
τ_{bo}	Binary coalescence for drops of initial diameter
$\tau_b{}^*$	Binary coalescence for drops of reference diameter
$\tau_i{}^*$	Coalescence time at the coalescence interface
ω	Angular velocity

Abstract of Thesis Submitted to the Senate of Universiti Putra Malaysia in Fulfillment of the Requirements for the Degree of Master of Science

THE DESIGN OF CRUDE PALM OIL CLARIFIER

By

SULAIMAN A. S. AL-ZUHAIR

May, 1998

Chairman: Associate Professor Dr. Ir. Tan Ka Kheng
Faculty: Engineering

The objective of this research was to study the settling characteristics of crude palm oil (CPO), and use them to design a crude palm oil settler so that to increase the oil recovery, and hence the oil loss in the effluent can be minimized.

The apparent viscosity (η) of CPO after dilution with water was measured and an equation for its behaviour with shear rate (γ) and temperature (T) was derived:

$$\eta = 898 \exp (1900/T)\gamma^{(-0.61)}$$

The equation was used to model CPO settling. Two approaches to determine the design criteria of the CPO settler were followed - conventional solid/liquid analysis, as proposed by Lim (1977), and liquid/liquid analysis. The liquid/liquid analysis underestimated the required settler height by 38-53%, and the conventional approach by 55-63%. Finally, a coagulation Jar test was carried out to examine the effects of five coagulants in the oil recovery from the effluent. The results showed that the use of coagulant can reduce oil loss in the clarifier. The recovered oil was 3% of the plant throughput.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains.

REKABENTUK PENULINAN MINYAK SAWIT MENTAH

Oleh

SULAIMAN A. S. AL-ZUHAIR

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Pengerusi: Professor Madya Dr. Ir. Tan Ka Kheng
Faculti: Kejuruteraan

Objektif penyelidikan ini ialah untuk mengkaji ciri-ciri CPO (minyak sawit mentah), dan menggunakannya untuk menentukan rekabentuk "settler" untuk minyak sawit mentah dan mengurangkan kehilangan minyak dalam pengaliran air yang mengandungi bahan buangan.

Kelikatan minyak sawit mentah selepas penulinan disukat dan persamaan yang menentukan perbezaannya dangan tahap kejelasan dan suhu ditentukan *oleh* $\eta = 898exp(1900/T)\gamma^{(-0.61)}$. Persamaan ini boleh disyorkan untuk digunakan dalam "CPO settling models". Dua cara untuk mencari ciri-ciri rekabentuk "CPO setteler" adalah seperti berikut, pertama ialah cara analisis pepejal/cecair menghasilkan kurang anggar

tinggi "setteler" sebanyak 38-53%, manakala keputusan cara konvensional menghasilkan 55-63% kekurangan daripada anggaran. Akhirnya ujikaji bikar pemejalan dijalankan untuk memeriksa kesan penambahan lima jenis pemejal dan keputusan ujikaji menunjukkan bahawa penambahan ini mengurangkan kehilangan minyak di dalam penulin. Minyak yang dapat diperolehi ialah 3% deripada jumlah minyak yang dihasilkan.

CHAPTER I

INTRODUCTION

When first expressed from the fruits, palm oil (a product even more crude than the commercial *crude palm oil*) is dirty and unpalatable, containing water, soluble impurities and a considerable amount of debris. The composition of the oil straight from the screw press is 40% - 75% oil, 10% - 40% water and 6% - 25% non-organic solids (NOS).

To remove the impurities, the oil is stood in a clarifier where the oil and water (together with most of the debris), being inmiscible liquids, separate out. The heavier water and debris settle to the bottom while the relatively clean and dry oil rises to the top and is skimmed off.

The design of the clarifier is very important as it is a major wastewater producer. However, the laws of settling, such as Stokes law, cannot be easily applied to it because the sizes, shapes and densities of the solid particles are so variable. In addition, water is present as a third confounding factor in the system.

The main design parameters used today are determined empirically (PORIM, palm oil factory process handbook, 1988). This is neither scientific nor economically efficient.